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Modelling of unsteady airfoil aerodynamics for the prediction of blade standstill vibrations

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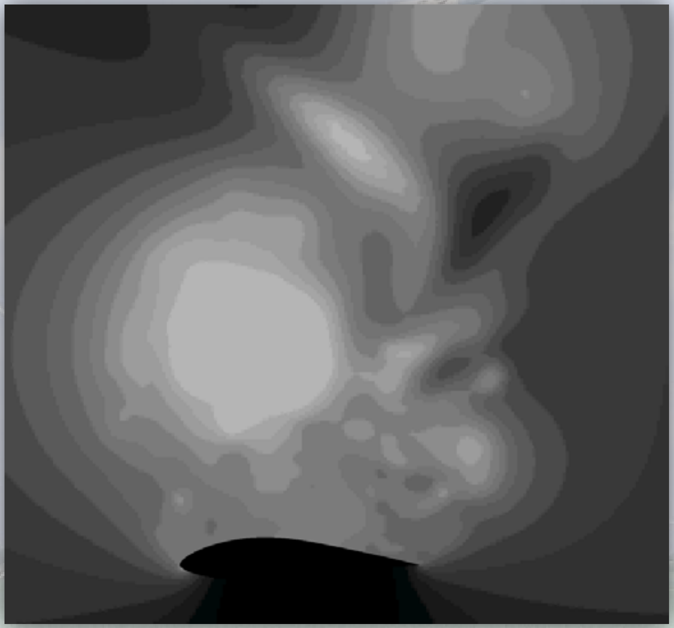
Contents

1. Introduction

Blade standstill vibrations

<u>Vortex-induced</u>

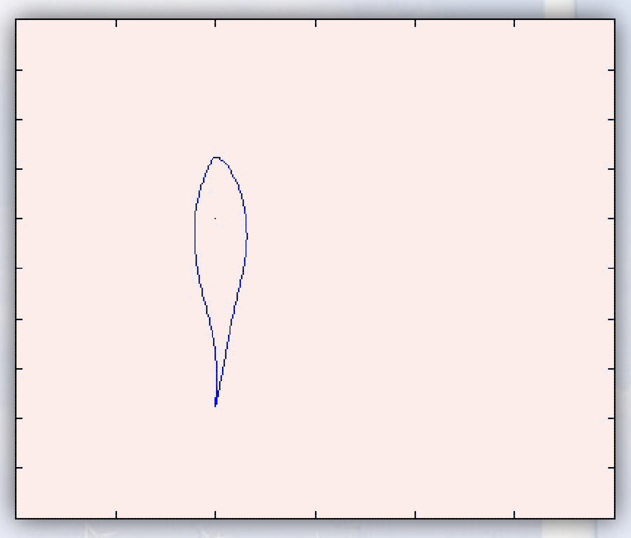
Stall-induced



Blade standstill vibrations

Vortex-induced

Stall-induced



2. Tools and methods

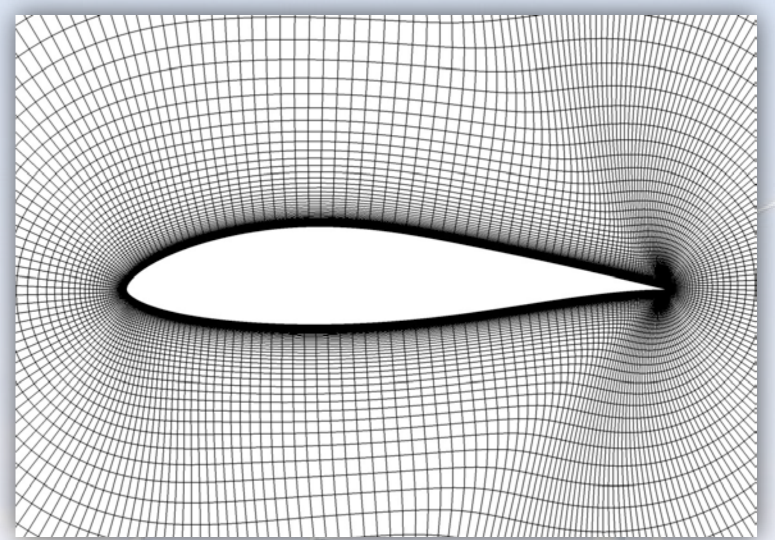
2.1 Procedure

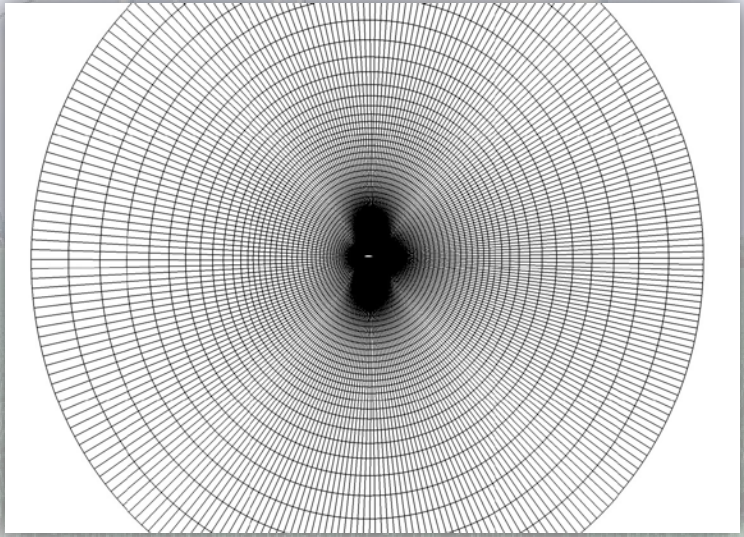
- Temporal lag of the aerodynamic response was quantified by means of an engineering aerodynamic model
- Parameters of the model were adjusted to match the dynamic lift coefficient and dynamic drag coefficient loops obtained during the CFD simulations
- Resulting parameters were considered representative of the respective CFD simulations.
- Angles of attack used in the present work were defined with respect to the flow velocity relative to the airfoil. Airfoil motion was taken into account.

2. Tools and methods

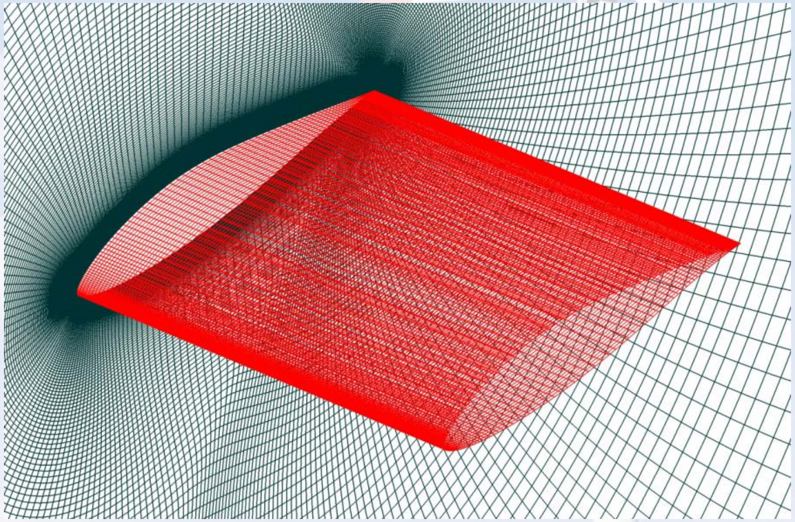
2.2 2D and 3D N-S solvers and computational setup

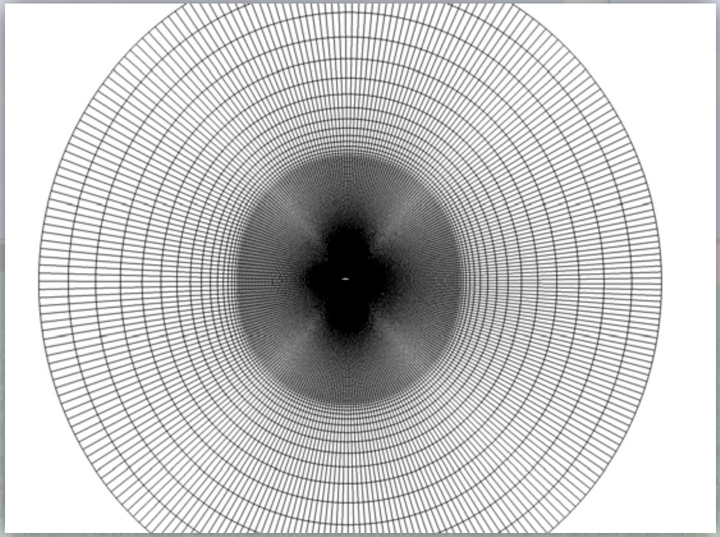
2D: $33 \cdot 10^3$ grid cells





3D: $13 \cdot 10^6$ grid cells





2. Tools and methods

2.3 Engineering model

Dynamic lift coefficient: $C_L^{Dyn} = C_L^{St}(\alpha_E)$

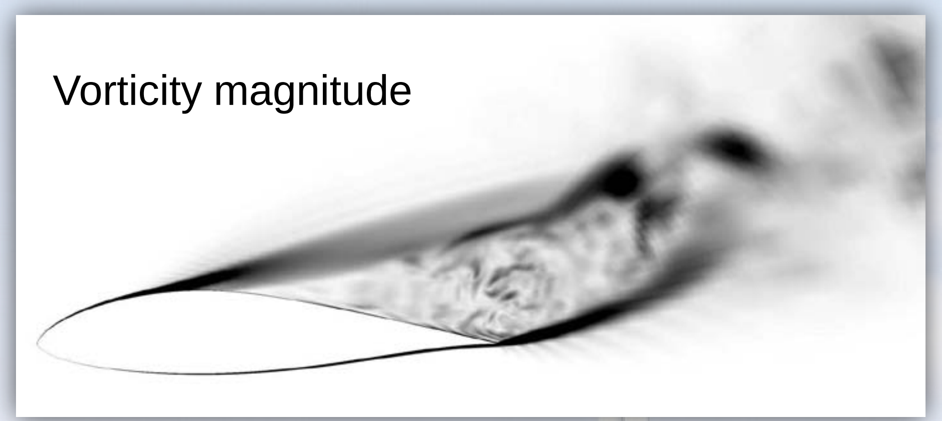
$$\alpha_E = \alpha_{3/4}(1 - A_1 - A_2) + x_1 + x_2$$

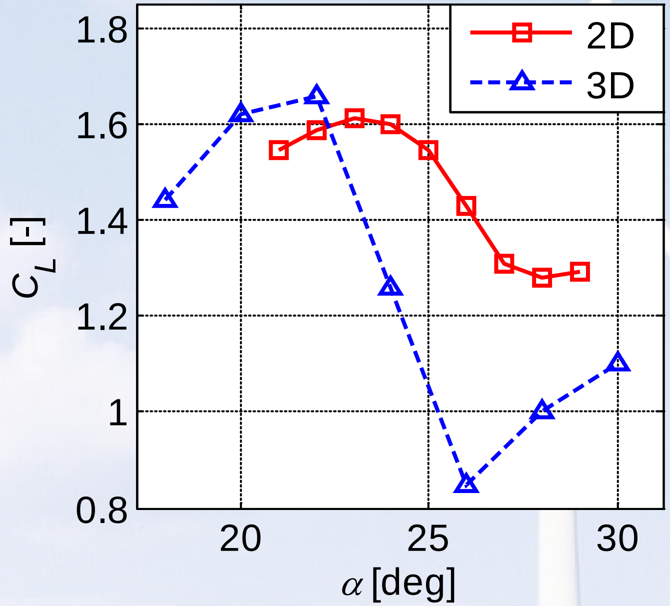
$$\dot{x}_i + \frac{2V_{rel}}{C} b_i x_i = b_i A_i \frac{2V_{rel}}{C} \alpha_{3/4}; \quad i = 1, 2$$

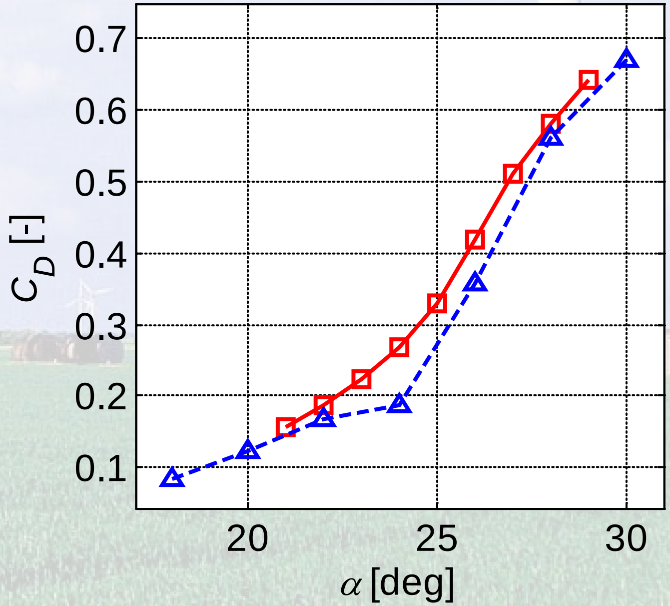
Dynamic drag coefficient: $C_D^{Dyn} = C_D^{St}(\alpha_E) + (\alpha - \alpha_E) C_L^{Dyn}$

3. Results

3.1 Computations on a non-moving airfoil



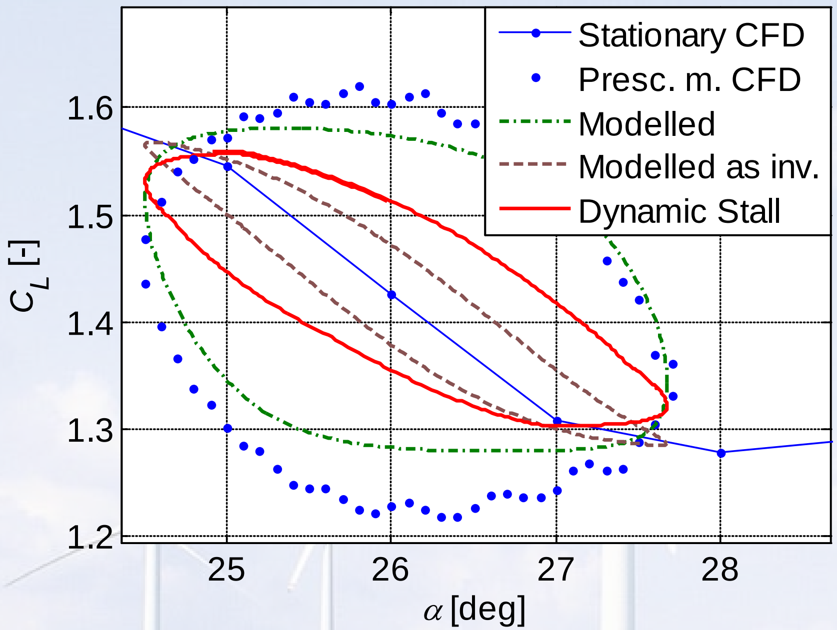


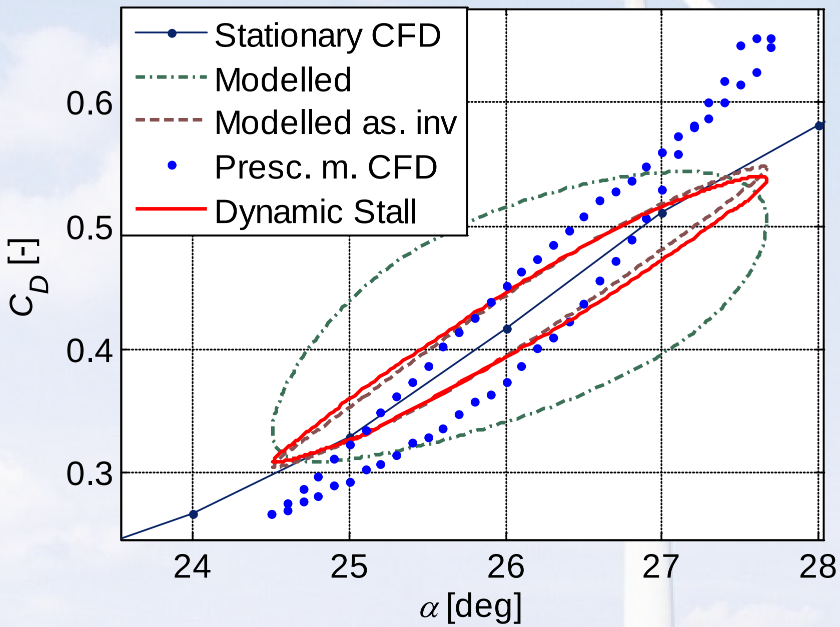


- Complex flow
- Separation
- 3D: 24 degrees AOA
- 2D: 26 degrees AOA
- Re = $6 \cdot 10^6$

3. Results

3.2 2D computations in prescribed motion

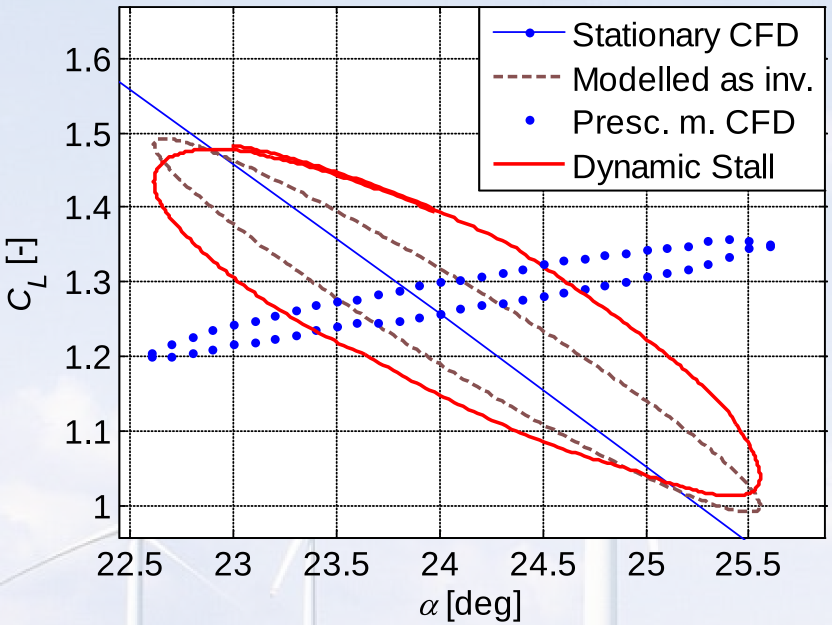


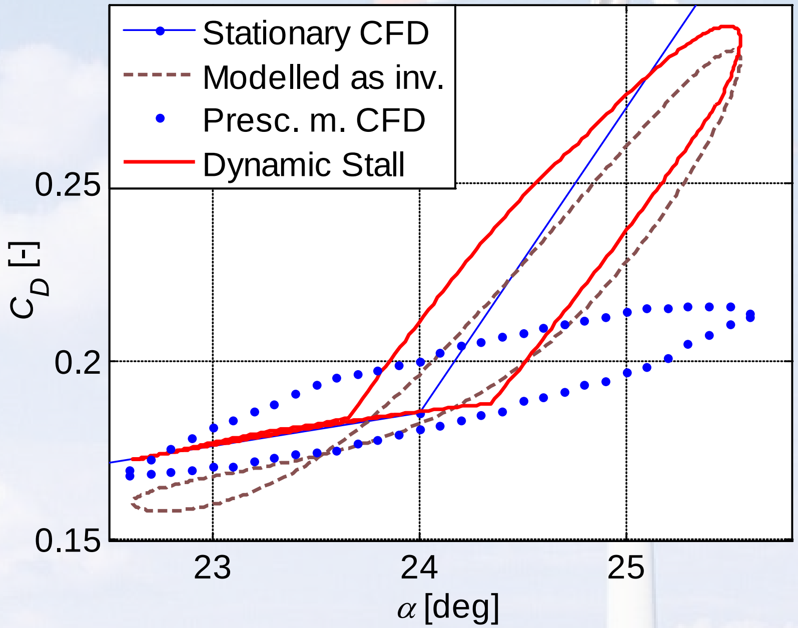


Loop direction: counter clockwise

3. Results

3.3 3D computations in prescribed motion





Loop direction: counter clockwise

4. Conclusions

- The openings of the C_L loops predicted by CFD were different than predicted by the engineering model with constants based on inviscid flow or the Beddoes-Leishman type model.

- The approximate C_L loop resulting from the 2D CFD was modelled by the engineering model.

- The slope of the C_L loops from the 3D CFD had opposite sign to those from the 2D CFD.

- Modelling the 3D behaviour with the engineering models proved difficult, indicating that the present engineering approach may be insufficient.

- State-of-the-art aeroelastic codes may predict vibrations inaccurately

5. Future work

- Perform similar investigations at other AOAs.
- Analyze the effect the change in the sign of the lift slope has on the aerodynamic damping.
- Investigate the influence of blade twist and taper on the relevant aerodynamic characteristics.

Thank you!